# The Two in Bragg's Condition Is Neither a Dimension nor an Exponent but a Round Trip

— Assembling the path difference of two reflected rays directly from geometry gives $d\sin\theta$ going down and $d\sin\theta$ coming back, summing to $2d\sin\theta$ with 12-digit agreement — and doubling the spacing changes the angle while leaving the two in the formula untouched — [Paper 545]

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— *From thinking to syncing.* —

**Abstract**

**Bragg's condition $2d\sin\theta = n\lambda$ contains a two.What this paper shows is that the two comes from a round trip rather than from a dimension or an exponent, and that dropping it makes the spacing come out exactly twice too large.No new theorem or law is claimed. First, assembling the path difference from geometry splits it into two equal parts——$d\sin\theta$ going down and $d\sin\theta$ coming back, summing to $2d\sin\theta$ with 12-digit agreement** (Section 2). **Second, and this is the core.Dropping the two makes the spacing come out exactly twice too large——2.0879 angstroms becomes 4.1758 for copper (111), a ratio of 2.000000** (Section 3). **Third, the correct side matches the known value——2.0879 agrees with the literature value of about 2.087 angstroms within 0.01** (Section 3). **Fourth, the dropped side does not——4.1758 misses by more than one angstrom: the far side of the boundary** (Section 3). **Fifth, the two does not move——doubling the spacing from 2.087 to 4.174 angstroms takes the angle from 21.6598 to 10.6347 degrees while the two in the formula stays** (Section 4). **Sixth, the separator is what the two counts——a number of traversals, not a number of dimensions nor a power** (Section 4). **Keywords**: Bragg's law, X-ray diffraction, crystal, round-trip path difference, lattice planes.

**Scope of this paper (scope note)**: **No new theorem or law is claimed——Bragg's condition and its geometry are standard.Dynamical diffraction theory is not entered——absorption, extinction and multiple scattering are not treated; only the kinematic path difference.No crystal structure is determined——one plane and one peak are treated, and no procedure for structure solution is described.Experimental error is not treated——errors in reading peak positions and the calibration of instrument constants are not the subject.No refraction correction is applied——the slight departure of the refractive index from one inside a crystal is ignored.No other two is bound to this one——it is not claimed to share a root with other twos in the corpus; only that this one comes from a round trip.Relation to earlier papers**: **Paper 157 took a census of squares——this adds one entry, though not a square: it is the two of a round trip.Paper 335 showed that a round trip changes the exponent——there a round trip moved a power; here it appears as a coefficient. The same round trip surfacing differently.Paper 269 showed that what a crystal forbids is periodicity rather than symmetry——Bragg's condition applies only where there is periodicity, so that subject is a premise here.Paper 300 showed that sharing a root is decidable——this two and the two of a square are separate roots under the criterion of what a quantity carries.**What is added is **assembling the path difference from geometry to 12-digit agreement**, **confirming the two contributions equal**, **showing that dropping the two multiplies the spacing by exactly** **2.000000**, **checking both sides against the known value**, and **placing the separator on what the two counts**.

## 1. Notation and the Question

**Setting**: **waves of wavelength $\lambda$ meet a stack of parallel planes spaced $d$ apart, at an angle $\theta$ measured from the planes. Reflections from adjacent planes reinforce when**

$$2d\sin\theta = n\lambda$$

**Observation 1.1**

**the origin of the two is not written down.From the formula alone one cannot tell whether it came from a dimension, from a square, or is a coefficient——and twos behave differently according to what they count.**

**Observation 1.2**

**there is a way to tell.Assemble the path difference directly from geometry and see where the two appears ——it can be counted from the figure rather than trusted from the formula.**

**Question**: **what does this two count?**

## 2. Assembling the Path Difference from Geometry

**Computation 2.1**: adding the two parts of the extra distance travelled by the wave reflected from the lower plane: the descent and the return, each $d \sin\theta$.

| $d$ | $\theta$ (degrees) | sum from geometry | $2d \sin\theta$ |
|---|---|---|---|
| 2.00 | 10.00 | 0.694592710668 | 0.694592710668 |
| 2.00 | 21.65 | 1.475743181838 | 1.475743181838 |
| 2.00 | 45.00 | 2.828427124746 | 2.828427124746 |
| 3.50 | 21.65 | 2.582550568217 | 2.582550568217 |

> **Observation 2.2**
>
> agreement to 12 digits every time.The difference is exactly zero——a check that the formula follows from the geometry, not a claim.

> **Observation 2.3**
>
> the two contributions are equal.Descent and return both give $d \sin\theta$——which is why the sum doubles. The two counts “twice”.

> **Observation 2.4**
>
> equality of incidence and reflection is doing the work.Were they unequal the two contributions would differ and no two would appear——behind the two lies the assumption of specular reflection.

## 3. What Dropping the Two Does

**Computation 3.1**: with copper $K$-alpha radiation at $1.5406$ angstroms and the $(111)$ first peak at $2\theta = 43.30$ degrees, computing the spacing both ways.

| formula | spacing obtained |
|---|---|
| $d = \lambda / (2 \sin \theta)$ | **2.0879** angstroms |
| $d = \lambda / \sin \theta$ (two dropped) | **4.1758** angstroms |
| ratio | **2.000000** |
| literature value for copper (111) | about 2.087 angstroms |

> **Observation 3.2**
>
> **this is the core.Dropping the two multiplies the spacing by exactly 2.000000——not an error but the coefficient carried straight into the answer.**

> **Observation 3.3**
>
> **the correct side matches.2.0879 against about 2.087, within 0.01 angstroms——a comparison with an independently known value, and a check that can fail.**

> **Observation 3.4**
>
> **the dropped side does not.4.1758 misses by more than one angstrom——the far side of the boundary. Examining both sides shows the check is not vacuous.**

> **Observation 3.5**
>
> **the error is inconspicuous.A spacing of 4.1758 angstroms is not in itself unreasonable for a crystal——without comparison against a known value it would pass.**

## 4. The Separator

**Computation 4.1**: **computing the angle when the spacing is doubled: 21.6598 degrees at $d = 2.087$ and 10.6347 degrees at $d = 4.174$.**

**Observation 4.2**

**doubling $d$ halves $\sin\theta$.The two in the formula does not move——it depends on neither $d$ nor $\lambda$ nor $\theta$. It is a constant.**

**Observation 4.3**

**the separator is what the two counts.It counts traversals——not dimensions and not a power, so changing either leaves it alone.**

**Observation 4.4**

**one entry for the census of Paper 157.Though not a square——listed in the same table it needs a separate column, as the two of a round trip.**

**Observation 4.5**

**it surfaces differently from Paper 335.There a round trip changed an exponent——here it appears as a coefficient, so exponent and coefficient are separate roots for one round trip.**

**Observation 4.6**

**the subject of Paper 269 is a premise.There, what a crystal forbids is periodicity——Bragg's condition applies only with periodicity, since without evenly spaced planes there is no $d$.**

**Observation 4.7**

**what is not said.Dynamical diffraction theory is not entered——absorption, extinction and multiple scattering are untreated, and the refraction correction inside the crystal is ignored.**

## 5. Roll Call and Closing

1. **geometry and formula agree to 12 digits** (Computation 2.1): **difference exactly zero.**
2. **the two contributions are equal** (Observation 2.3): **both $d \sin\theta$.**
3. **specular reflection does the work** (Observation 2.4): **otherwise no two.**
4. **correct formula gives $\mathbf{2.0879}$ angstroms** (Computation 3.1): **matching literature.**
5. **dropping it gives $\mathbf{4.1758}$** (Computation 3.1): **the core.**
6. **the ratio is exactly $\mathbf{2.000000}$** (Observation 3.2): **the coefficient carries over.**
7. **the dropped side misses** (Observation 3.4): **the far side.**
8. **the error is inconspicuous** (Observation 3.5): **it would pass unchecked.**
9. **doubling $d$ halves $\sin\theta$** (Computation 4.1): **the two stays.**
10. **the separator is what it counts** (Observation 4.3): **traversals.**
11. **different surfacing from Paper 335** (Observation 4.5): **exponent or coefficient.**

**Closing**: **Bragg's condition $2d\sin\theta = n\lambda$ contains a two.That two comes from a round trip——assembling the path difference directly from geometry gives $d\sin\theta$ for the descent and $d\sin\theta$ for the return, summing to $2d\sin\theta$ with 12-digit agreement. The agreement checks that the formula follows from the geometry rather than asserting anything. The two contributions are equal because incidence and reflection are equal, so behind the two lies the assumption of specular reflection.Dropping it makes the spacing exactly twice too large——with copper $K$-alpha radiation and the $(111)$ peak at $2\theta = 43.30$ degrees, the correct formula gives $\mathbf{2.0879}$ angstroms and the truncated one $\mathbf{4.1758}$, a ratio of exactly $\mathbf{2.000000}$. The correct side agrees with the literature value of about $2.087$ angstroms within $0.01$, and the dropped side misses by more than one angstrom, so the check is not vacuous. The error is inconspicuous, since $4.1758$ angstroms is not an unreasonable spacing and would pass unchecked.The separator is what the two counts——doubling the spacing from $2.087$ to $4.174$ angstroms moves the angle from $21.6598$ to $10.6347$ degrees while the two in the formula stays, depending on neither $d$ nor $\lambda$ nor $\theta$. It counts traversals rather than dimensions or powers, so changing either leaves it alone. It adds an entry to the census of Paper 157, though in a separate column, being the two of a round trip rather than of a square. Paper 335 found a round trip changing an exponent; here it appears as a coefficient, so the same round trip has separate roots. The periodicity of Paper 269 is a premise, since without evenly spaced planes there is no $d$.To be honest——dynamical diffraction theory was not entered; absorption, extinction and multiple scattering were untreated and only the kinematic path difference examined. No crystal structure was determined, only one plane and one peak treated. Errors in reading peaks and the calibration of instrument constants were not the subject, and the refraction correction inside the crystal was ignored. No claim is made that this two shares a root with other twos in the corpus. What can be said is that this two comes from a round trip, and that dropping it doubles the answer exactly, and no further.**

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